Interactive Tables in the Wild

Visitor Experiences with Multi-Touch Tables in the Arctic Exhibit at the Vancouver Aquarium

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Abstract

This report describes and discusses the findings from a field study that was conducted at the Vancouver Aquarium to investigate how visitors explore and experience large horizontal multi-touch tables as part of public exhibition spaces. The study investigated visitors' use of two different tabletop applications—the Collection Viewer and the Arctic Choices table—that are part of the Canada's Arctic exhibition at the Vancouver Aquarium. Our findings show that both tabletop exhibits enhanced the exhibition in different ways. The Collection Viewer table evoked visitors curiosity by presenting visually interesting information and engaged by supporting lightweight, playful, and open-ended information exploration. The Arctic Choices table enabled visitors to explore a variety of information about environmental and political changes within the Arctic in depth by providing detailed data visualizations. The application triggered a lot of insightful discussions among visitors.

Our study findings include a discussion of the factors that attracted visitors' attention and triggered interaction with both tabletop exhibits, the character and duration of information exploration, general exploration strategies, and factors that triggered social and collaborative information exploration. We also discuss usability issues of both tabletop applications alongside possible solutions.

Acknowledgements

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1 Introduction

The Vancouver Aquarium has always featured a vast amount of information about the Arctic as a habitat for many creatures and organisms. The old Arctic exhibit at the aquarium primarily featured fish tanks and printed visual and textual information to illustrate characteristics of the Arctic environment. As part of the renovations of the Arctic exhibit in 2009, the Vancouver Aquarium has shifted its thematic focus more toward presenting the changes within the Arctic that occur due to global warming and climate change. Alongside fish tanks and information murals, the new CANADA'S ARCTIC exhibit features a lot of interactive digital technology that allows visitors to explore information in a hands-on way. Among other interactive displays, two digital tables were installed as part of the exhibit (see Fig. 1.1). These two rear projected diffuse illumination tables (50" diagonal, 1280 $\times$ 720 pixels) [6] were designed by the exhibit design company Ideum[1]. In collaboration with the Vancouver Aquarium, Ideum developed two different applications—one for each table of the Arctic exhibit: the COLLECTION VIEWER application enables visitors to browse through a large collection of media items that show information about the Arctic environment, and the ARCTIC CHOICES application features interactive visualizations that illustrate environmental and political in uences of today's Arctic (see Fig. 1.2).

Figure 1.1: The two digital table exhibits at the Canaday's Arctic exhibit.

To explore how aquarium visitors experience these two large horizontal multi-touch tables as part of the Arctic exhibit we conducted a field study at the Vancouver Aquarium. We were in particular interested in investigating the following questions:

- What attracts visitors' attention to such walk-up-and-use digital tabletop exhibits? What kind of information presentations evoke particular curiosity?

[1] http://www.ideum.com

(a) Collection Viewer. (b) Arctic Choices.

Figure 1.2: The Collection Viewer and Arctic Choices applications.

- How do visitors approach digital tabletop exhibits? How can initial interaction attempts be characterized?
- How do visitors experience the information presented on both tabletop applications? How do they make sense of information they find?
- How do visitors experience direct-touch technology and multi-touch gestures as a means for open-ended information exploration?
- How can information exploration on both digital tabletop exhibits be characterized?
- What role does social and collaborative aspects play in visitors' information exploration on the digital tables?

Investigating these questions helps us to better understand the role that large interactive display technology can play within public spaces such as museums, aquariums, or art galleries. Findings from this study will help to establish a general understanding of how visitors explore information using large interactive tabletop displays and add to the discussion on how to design technology as well as applications that can facilitate information exploration in such public environments and add to a positive visitor experience.

This report summarizes our study findings on both the Collection Viewer and the Arctic Choices table. We first provide an overview of our study method including data collection and analysis. Our study findings are divided in three parts. We first describe findings that we observed on both tabletop applications. We discuss how visitors generally approached the two tabletop exhibits, how the form factor of the tables in uenced visitors' behavior, and how visitors experienced direct-touch interaction as a means for information exploration.

Our study findings are then structured based on particular observations regarding the Collection Viewer and the Arctic Choices table. For both tabletop applications we first brie y describe the characteristics of the application in focus and then discuss our findings on each application in detail. Our report concludes with a comparison of each application's strengths and weaknesses and some design recommendations for possible future iterations. We also provide an outlook to topics that we will focus on in future analysis of our study data.

2 Study Method

Our field study at the Vancouver Aquarium followed an ethnographic approach that enabled us to observe visitors' interactions in-situ while limiting biases of visitors' activities introduced by the study setup to a minimum [8]. As researchers conducting the study we are not affiliated with the Vancouver Aquarium or Ideum, and we were not involved in the development of the tabletop applications in focus.

2.1 Study Setup

The study was conducted approximately two months after the first deployment of the interactive tables at the Arctic exhibit. For the study, two small unobtrusive but high-resolution video cameras were installed on the ceiling above and beside one of the digital tables to record visitors' activities and gestures around and on the interactive surface from different perspectives (see Fig. 2.1). Instead of changing the location of the cameras to capture activities on both tables, we kept the cameras in place and exchanged the applications running on the table in the cameras' focus once during each study day. The study took place during eight days: one weekend before and six consecutive days during the Christmas school holidays in Vancouver.

2.2 Data Collection

During the time of the study we collected field notes and recorded video and audio data on-site for three to four successive hours each day. Study sessions took place between 11am and 5pm during both high and lower visitor run. A sign informed visitors about the observations taking place and video being recorded. During each study session, an examiner was present at the Arctic exhibit, taking notes of the interactions and activities that took place around the table. The examiner wore casual clothes to blend in with the visitor crowd and kept sufficient distant from visitors interacting with the study application to interrupt or bias their activities as little as possible. In total, approximately 20 hours of video data was collected with each camera (approx. 10hours focusing on each of the two applications).

2.3 Recruited Participants

Besides taking field notes and capturing video and audio data of visitors' use of the two tabletop applications, we also recruited groups of people and accompanied them on their visit through

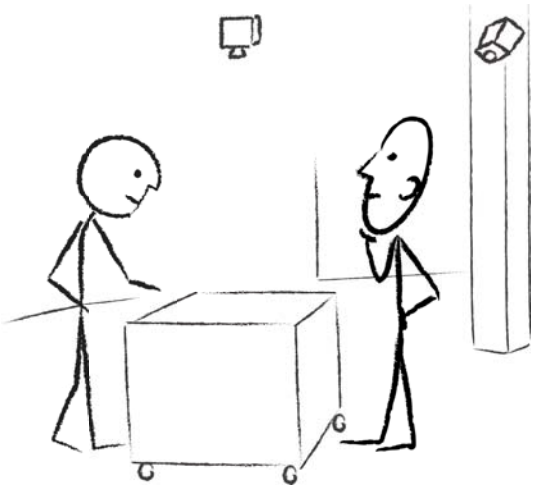


Figure 2.1: Study setup.

the aquarium. We in particular gathered their comments on the two tabletop exhibits. This approach, that has also been referred to as 'shadowing' [4], enabled us to gain insights into the interactions and activities of visitors with other traditional and digital exhibits at the aquarium, such as fish tanks, small-screen interactive information kiosks, and information murals, in comparison to their interaction with the digital tables. We recruited four participant groups: three groups consisted of two adult participants each (one male, one female) and one group of six participants (three adults—two female, one male, and three children—all female). All groups were first asked to fill out a pre-questionnaire asking about their experience with computers and small as well as large display technology. Furthermore we asked them how often they had previously visited the Vancouver Aquarium and if they had interacted with the digital tables of the Arctic exhibit before. From these questionnaires that were filled out by all but two participants, we found that our participants were computer-savvy people who had used computers for more than five years on a regular basis. All of them had some experience with small direct-touch display technology such as cell phones. This experience ranged from '2-10 times' usage (two participants), 'frequent' usage (four participants), and 'daily' usage (four participants). All except one participant had used a large horizontal or vertical interactive display at least 2-10 times with one participant stating 'frequent' usage. All except one participant had visited the Vancouver Aquarium at least once but none of them had interacted with the digital tables in the Arctic exhibit before.

All participants were then asked to explore the aquarium as they normally would on a casual visit. Each group was accompanied by one researcher, observing their activities from a distance and occasionally asking about their experience of certain interactive exhibits. At the Canada's Arctic exhibit where the digital tables are located, the researcher conducted a brief interview with the groups asking about their experiences with each of the tables. These interviews included questions for their experience with the direct touch interaction and multi-touch gestures, the displayed information in general, their strategies to (collaboratively or individually) explore the displayed information, their experience with other (unknown) visitors interacting with the table

at the same time, as well as general concerns and usability issues. All interviews were audio recorded. After their visit of the Arctic exhibit, participant groups were thanked and debriefed. All recruited groups received free entrance to the aquarium as a reward for their participation in the study.

2.4 Data Analysis

For our analysis of video data we followed a two-pass analysis strategy that has been applied before in similar study contexts [7, 9]. To gain an overview of visitors' general activities using both the Collection Viewer and the Arctic Choices table we conducted a first transcription pass where we fast forwarded through all video data, only broadly transcribing interaction times and activities. These broad transcriptions provided an overview of the duration of interactions, instances of repeated interaction, as well as general activities and pointed us to particular incidences that we marked for further and more detailed analysis.

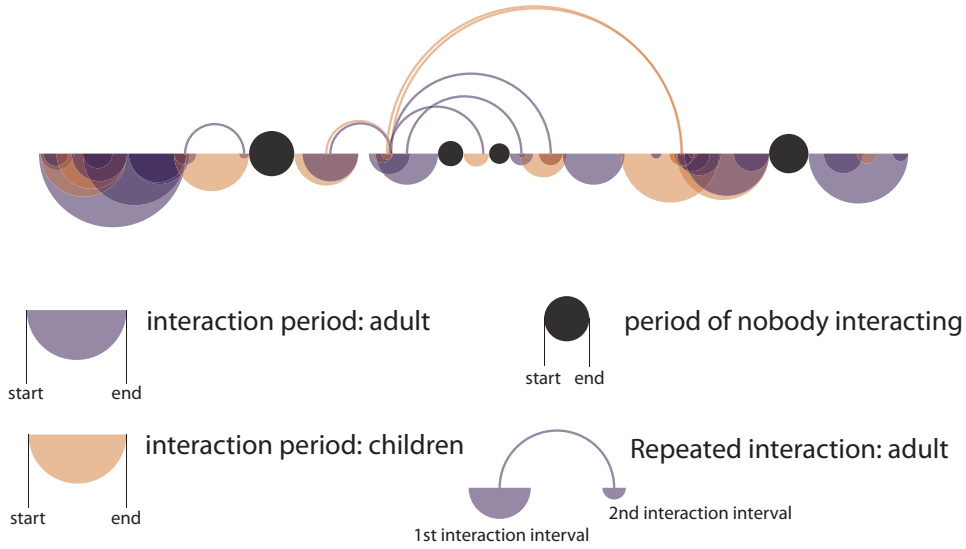


Figure 2.2: Visualization of interaction periods of adult and child visitors.

We also visualized the data from our high-level transcription pass for further analysis (see Fig 2.2). Each solid arc on the bottom represents an interaction period (blue: adult visitor, orange: child visitor). Black circles represent periods where nobody interacted with the table. Colored arc strokes connect all interaction periods of a single visitor, and therefore can provide an overview of instances of repeated interaction. These visualizations were constructed for four study days so far (see Appendix at the end of this report) and can reveal patterns of interaction as well as particularly interesting interaction periods that are worth revisiting for a more detailed analysis. While we have not analyzed all of these visualizations thoroughly, we plan to use them to compare the activity patterns on both tables. In future analysis steps, we also will analyze

especially busy interaction periods, periods of only children or adults interacting, and activity patterns of certain visitors that interacted with the table several times.

Data generated from the high-level transcriptions were used to select a subset of video data for a more in-depth transcription and analysis. In particular, we analyzed a subset of video data for visitors' use of multi-touch gestures on the Collection Viewer. We will report on the findings of this in-depth gesture analysis in a future report.

Besides analyzing the video data, we transcribed all interviews with our recruited visitor groups. These interview transcriptions were then analyzed by categorizing participants' comments based on the general topic they were referring to, such as direct touch interaction, technology form factor, interaction techniques, information design, usability issues, and social experience.

This report focuses on the our general observations of visitor activities with and experience with both the Collection Viewer and Arctic Choices table based on our high-level video analysis and in-depth analysis of interviews with recruited visitor groups. The following sections discuss the findings of this analysis.

3 General Experience of the Digital Tables

Before describing the findings for each of the two tables individually, we comment on several aspects that we observed with both tabletop exhibits. Both digital tables evoked a lot of curiosity among visitors. In particular the direct-touch interaction as a means to explore content was appreciated by visitors. We found that the form factor of the table invited for activities beyond information exploration. While this resulted in some rough usage, the construction of both tables withstood such situations without any problems.

3.1 General Acceptance of the Tabletop Exhibits

Digital tables can be still considered as a novelty, visible in visitors' reactions to the two tabletop exhibits. For instance, a lot of visitors posed in front of the table and took pictures of the tabletop hardware and interfaces. This novelty effect explains some of the curiosity that both digital tables evoked within the Arctic exhibit.

During our observations, both tables were in nearly constant use. Although the tabletop interfaces were not visible from far due to the horizontal orientation of the table surface, the form factor of the tables as well as the interaction of other visitor groups drew people's attention toward the tabletop exhibits. This latter finding refers to the 'honey pot effect'—the attention of visitors to an exhibit attracts other visitors' attention—that has been observed in previous studies on interactive technology in public spaces [2, 3, 4].

In particular children approached the tabletop displays without hesitation and started to touch and explore the interfaces immediately. Adults tended to approach the tables more tentatively but not less interested. They often watched other visitors' interactions for a while before interacting themselves. One study participant stated: "*[...] it was kind of nice to watch for a while, because then I could get a sense of what was on the table* [and] *how you interact with things*." We found that both tables integrated well within the Arctic exhibit, attracting a lot of visitor attention but also guiding attention toward other exhibits close-by. For instance, we observed that some visitors would first pay attention to the information murals on the walls close by the digital tables (see Fig. 1.1 for the murals in the background), before interacting with one of the tables itself. Vice versa, visitors' attention would also shift from the digital tables toward the information murals. This shows that, despite of the current excitement around digital exhibits in public spaces such as museums and aquariums, traditional static visual and textual information still play an important role within exhibitions. A combination of both digital and traditional information presentation can therefore greatly enhance visitors' experience of exhibitions.

3.2 Positive Experience of Direct-Touch Technology

The multi-touch interaction was experienced as fun and playful. Nearly all visitors that payed attention to one of the digital tables, tried to touch them at some point. Some participants commented on how they appreciated the responsiveness of the interactive tables. As discussed above, all recruited participants were familiar with direct-touch technology through the use of cell phones or portable music players and all but one had at least some experiences with large interactive displays. Participants commented on how their previous experience with direct-touch technology positively in uenced their ability to interact with the tables of the Arctic exhibit. They also acknowledged the simplicity of both the Collection Viewer's and the Arctic Choice's table interaction techniques. One participant stated: "[...] *As a whole it is pretty obvious to interact with it. It has made a big difference that Apple* [e.g. iPod Touch & iPhone] *has been out. I mean, if it wasn't for the touch we wouldn't know how to make it bigger or smaller or slide things around.* [...] *I have got an iPhone. And my daughter has got an iTouch. So, yeah, sure. And then you got James Bond movies and stuff, so... It's* [examples of direct-touch interaction] *around. But yeah, it is pretty simple. Pretty obvious.*" Our observations and statements from participants show that visitors were able to quickly understand how to control the digital tables without instructions—an important requirement for walk-up-and-use interactive exhibits.

3.3 Form Factor Invites Appropriation

With its horizontal surface that resembles traditional tabletop surfaces, visitors frequently treated both tables as a robust basic commodity. They would frequently place food items such as (open) bottles, coffee mugs, cookies, or toys on the tabletop surface to have the hands free for interaction. Such items were typically placed on the edge of the tables—outside of the tabletop workspace—and left there for extended periods of time (see Fig. 3.1(a)).

(a) Food items and toys on the Collection Viewer table.

(b) Child lying on the Arctic Choices table and reaching for the lens tool.

(c) Woman sitting on the Arctic Choices table.

Figure 3.1: Instances of re-appropriating the digital tables.

We also noticed instances of parents putting down their babies on the table or toddlers lying, sitting, or standing on the tabletop surface that they otherwise could not reach (see Fig. 3.1(b)). We even noticed an adult who sat on one of the tables for an extended period of time to read a book (see Fig. 3.1(c)). These observations point out the importance of the use of highly robust

hardware to build public tabletop installations. Other than vertical displays, the physical form factor of a digital tables suggests usage scenarios that go beyond direct-touch interaction using the hands and that can involve placing heavy items on the tabletop surface as well as items that might spill or smutch the surface. Given the physically highly robust Ideum tables, however, we were excited to see how naturally visitors applied their experience with traditional tables to the two tabletop exhibits and appropriated them according to their needs.

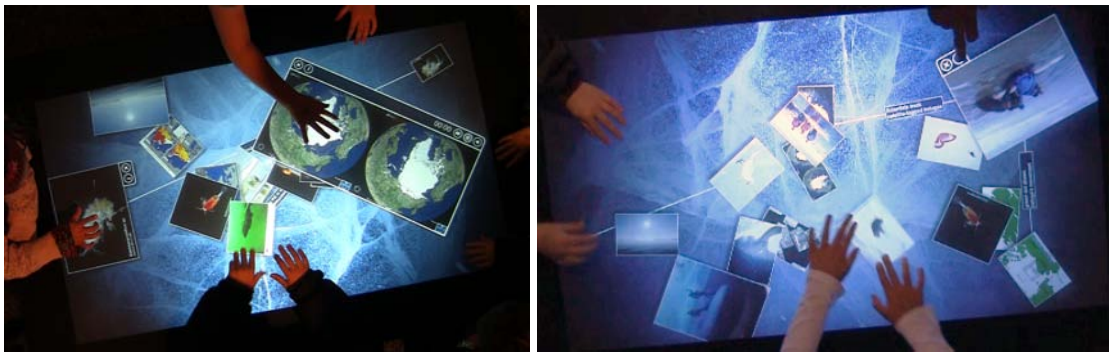
The ability to temporally place items on the table in order to explore information with both hands is definitely a benefit of tabletop exhibits over interactive wall displays since we observed that visitors frequently carried items with themselves when they visited the Arctic exhibit.

4 The Collection Viewer Table

In the following sections we describe our findings on the Collection Viewer table. We will first provide a brief overview of the Collection Viewer application and then describe aspects of visitors' activities and experiences with the application.

4.1 The Collection Viewer Application

The Collection Viewer application consists of a selection of media items such as images, videos, and graphic animations that are distributed across the table surface in different orientations (see Fig. 4.1). This collection of media items covers topics around the Arctic environment, including living creatures, people, environmental issues, and research. The collection is constantly in ux: items are replaced with new images or videos, depending on how much visitors interact with them. For every media item that disappears, another one appears in a different location close to the center of the table surface. When first appearing on the table surface, all media items look like small static images. Videos and animations are overlaid with an icon showing a movie reel to make them distinguishable from static media items such as images (see Fig. 4.1(b), lower right corner). Contextual relations between media items are visualized through labeled connection lines (see Fig. 4.1(b)).



(a) Control buttons for image and video media items.

(b) Media items in the Collection Viewer.

Figure 4.1: The Interface of the Collection Viewer.

The Collection Viewer supports a set of commonly used multi-touch gestures[1][2] [7, 9, 11]

[1] http://www.perceptivepixel.com/

[2] http://www.microsoft.com/surface/

to enable the translation, rotation, and scaling of media items. In addition, each media item is equipped with buttons to bring up textual information about its content or to delete the item from the table surface. Video items have additional play, pause, and reverse buttons (see Fig. 4.1(a)).

4.2 Findings on the Collection Viewer

Our findings are structured around the following topics:

- Overall appeal and attraction—which factors direct visitors' attention toward the Collection Viewer?
- Duration of interaction—how long do visitors interact with the installation in average, and how often do they come back to interact a second or third time?
- Interaction design and interaction techniques—how do visitors' learn to control and explore information on the Collection Viewer?
- General exploration strategies—how do visitors explore the information presented on the Collection Viewer table?
- Individual & collaborative use—how do social and collaborative interactions evolve around the Collection Viewer table?

4.2.1 The Role of the Collection Viewer as Part of the Arctic Exhibit

In general, the visitors that we recruited particularly for our study were interested in the information presented by the Collection Viewer and found that it, overall, enhanced the Arctic exhibit. Participants appreciated the connection between information shown in the Collection Viewer with other exhibits: "*The information we found* [in the Collection Viewer] *was really interesting. It is sort of like little snippets of information. And it was kind of nice: What I was noticing is that a lot of information here relates back to things we have already seen in the exhibit. So it was kind of nice to see it at the end. Because we could go: oh yeah, that fish was over here.*" This comment shows that visitors were able to draw a contextual connection between information presented in the Collection Viewer and other exhibits within the Arctic exhibit. This might have helped visitors to recall and memorize experiences or information that they had seen somewhere else in the Arctic exhibit.

4.2.2 Playful Interaction as an Entry Point

Character of Initial Interaction

As stated before, the form factor and number of people interacting with the Collection Viewer evoked visitors' attention and led them toward the exhibit. A more in-depth interaction analysis showed that interactions with the Collection Viewer usually started with visitors touching a media item with one hand (commonly the index finger) and move the item around on the table. We observed this behavior equally often with adults and children. This initial interaction can

be interpreted as a brief exploration of what kind of experience to expect from the exhibit. It satisfies initial questions such as:

- Is this exhibit interactive?
- Can I control media items and how?
- How does it *feel* to manipulate a media item via direct-touch?

Based on our observations we believe that the third question was the one that led visitors to a first interaction attempt. As discussed above, the Collection Viewer was nearly constantly in use so most visitors joined the table when it was already populated with other visitors interacting. Most visitors therefore often already have had the opportunity to see 1.) that the table is interactive, and 2.) how to manipulate it (questions one and two). The curiosity of how the interaction actually felt, however, had to be experienced by each visitor individually and could not be satisfied by pure observation. Therefore, most visitors tried to interact with the Collection Viewer at least once.

Playful Interaction

Most interactions with the Collection Viewer can be characterized as playful. In particular children often tossed media items around for extended time periods without really paying much attention to content. While adults often interacted less vividly than children, we found that the playful behavior of children attracted the attention of adults and resulted in little crowds of visitors (up to 10 to 15 people, some interacting some just watching) surrounding the Collection Viewer. The direct-touch, free-form interaction supported by the Collection Viewer enables this kind of playful interaction really well. It can serve as an important entry point [5] that draws visitors' attention toward the offered information and encourages first interaction.

4.2.3 Duration of Interaction and Repeated Engagement

We found that the Collection Viewer table was used very actively by aquarium visitors. Our high-level video analysis that included data from four study days (180 adult interaction instances, 170 children interaction instances, approximately 4.5 hours of video data) revealed an average interaction time of 2.17 minutes with children interacting for a slightly longer period of time (2.39 minutes in average) than adults (1.94 minutes in average). During the analyzed 4.5 hours of video recordings, we counted 53 instances where the Collection Viewer was not in use. Such 'empty' periods lasted for 1.18 minutes in average. 20% of the children and 14% of the adults we observed interacted with the Collection Viewer several times. Most of them came back for one second interaction but we also observed visitors coming back as much as six times. While a more complete analysis (including the whole data set) of the duration of interaction is required, these numbers show that the Collection Viewer as an exhibit was quite successful. In the future we would like to further analyze the character (and duration) of repeated interaction and compare the differences between the interactions of adults and children with the Collection Viewer more closely.

4.2.4 Interface & Interaction Design

Control of Media Items Easy to Understand

The one participant that had never interacted with a large interactive display before mentioned how he intuitively understood that media items on the Collection Viewer were interactive and would react to direct touch interaction. He explained: "*What is really weird is that I have never interacted with something like this before since I don't have an iPhone—but I have used one. So my instinct was to do this* [he mimics a pinching gesture with his index finger and thumb to resize a media item]. *And I was like 'oh my god' It works... I knew what to do. That was amazing.*" Along the same lines, a participant from another group commented: "*You don't have to know anything. Because you do something and something happens. You don't have to think about it at all.*"

Our in-depth video analysis of multi-touch gestures applied on the Collection Viewer, suggests that visitors often tried to interact with the media items as if they would interact with paper on a physical table. The open-ended implementation of multi-touch gestures on the Collection Viewer allows for a variety of gestures to achieve the same response. For instance, media items can be resized using one or two hands. In this way, visitors were able to control media items immediately without any previous training or instructions. Initial interactions quickly led to some kind of response from the system and invited further exploration.

Fine-Level Control Dif cult

While visitors quickly understood how to control media items, we noticed more problems with achieving some fine-level control of media items. This is partly because of the interaction of multiple visitors at the same time that seemed to sometimes confuse the touch recognition and therefore caused some unpredictable reactions of media items. Furthermore, the 'fat finger problem' inherent on all direct-touch systems makes delicate manipulations more difficult. Commenting on the unpredictability of item manipulations, one visitor stated: "*You touch something and it is pulling out something else, not necessarily something you wanted to look at. I can see where that can get really frustrating. You have to take some patience to kind of work with the quirks of it.*" Due to the problems stated above, some participants found the media items "*hard to control*" and even avoided certain interactions that they knew were generally supported and would have been useful. For instance, we found that visitors hardly ever rotated media items but, instead, tried to change their position around the table to see them from a better angle. One participant explained: "*I was a little tentative rotating it* [the media item] *because sometimes when I touched it, it would do some unpredictable things, like it would go flying off for some reason. So I was like: it is good. I'll leave it.*" Scaling or moving media items around seemed to work more reliably and therefore was much more often applied.

It is difficult to improve the ability to control media items through changing the interface or the interaction design of the Collection Viewer. While the engine for touch recognition could probably be improved, the use of multi-touch gestures on an interactive display that is used by multiple people at the same time will always cause some interferences that result in unpredictable behavior of content. However, our observations suggest that one characteristic of the Collection Viewer aggravated this problem. As soon as the geometric center of a media item passes the

edge of the table, it gets deleted. This design decision caused a lot of frustration among visitors. Since visitors would typically scale up media items of interest, these items were more likely to disappear on the table edge due to some unintended interaction. One participant commented: "*It is frustrating when pictures slide off and you can't get them back.*" Along these lines we observed a lot of instances where visitors tried to prevent media items to slide toward and disappear on the table's edge holding on to the item with both hands. Often, these attempts were not successful. The deletion of items should not be initiated immediately upon reaching the table edge. For instance, items could get stuck on the table edge for a while and slowly disappear, providing some time to move them back into the tabletop workspace if desired.

Participants also complained about 'stealing'. Touching an item causes a reaction, no matter if another person is currently interacting with it. Considering the amount of people who interacted at the same time on the rather small Collection Viewer table, so such 'stealing' instances happened frequently and caused a lot of frustration. One could improve the application by implementing a policy that prevents media items to react to other touches when they are 'in use', that is if someone already interacts with them or a video is currently playing.

4.2.5 Character of Information Exploration

Exploration Driven by Curiosity & Quality of Visual Elements

We found that the exploration of media items in the Collection Viewer was mostly driven by curiosity. Media items that visually stood out because they looked, e.g., particularly beautiful, cute, or bizarre often evoked the most attention and were explored further. One visitor commented: "*Something like that* [pointing at one media item] *I would look at because I don't know what it is.*" Pictures of animals were also popular. In several instances we observed children pointing out "*cute*" pictures of animals. Furthermore, videos received a lot of attention as well. One participant stated: "*I really liked the videos. I think, I was almost drawn more to the videos than to the photos with information. And they are nice short clips, so you kind of get a quick sort of piece of information and you can move on to the next thing.*"

Another participant, however, pointed out that she disliked how some of the videos showed scenes that could be directly observed in the fish tanks within the Arctic exhibit. She explained that a low resolution video snippet was much less attractive than discovering and observing things in the fish tanks. We can therefore conclude that while visitors highly appreciated videos as part of the Collection Viewer, there should be more focus on high quality video snippets showing information that relate to the fish tanks but provide information that cannot be directly observed by just watching creatures in these tanks live. For instance, the videos could show small creatures that the bare eye cannot perceive or the development of creatures that are on display in the fish tanks. Direct references to surrounding exhibits, can help to point out relations between exhibits and guide visitors from the video exploration in the Collection Viewer toward other exhibits such as the fish tanks.

The maps shown in the Collection Viewer attracted less attention: "*There were certain things that interested me more than others. And I found like the things that were maps—I found them not really interesting so I just started to ignore them after a while and only looked at the photographs and videos*." Another participant commented: "*They* [the maps] *just seemed really*

static and not visually interesting compared to the other material that was there. And it was sometimes difficult to read. I don't know. They almost look like screen captures or something—like they seemed kind of pixellated and kind of hard to read. So there just wasn't much there for me." Along these lines, some participants commented on the lack of resolution of some of the images and videos and of the digital table in general. Similar to the discussion on video snippets, these comments exemplify the need for high-quality visual presentations of information. Nowadays high-definition displays become more and more common and people's expectations toward high-quality digital media therefore increase. This is in particular important in a highly visual environment such as an aquarium that offers so many rich impressions through the presentation of living creatures. In order to successfully coexist near such visually rich information, digital media has to be presented in high quality.

Lack of Support of In-depth Information Exploration

Most visitors broadly browsed through the media items on the Collection Viewer table without really paying much attention to the textual information provided. While there are many ways to explore media items on a high level, we found that a more in-depth exploration is not supported well by the Collection Viewer. We noticed that the buttons of media items that lead to further (textual) information or start a video item were too small to reliably trigger a reaction from the system in a timely manner. Furthermore, the position of the 'information' button in close proximity to the 'delete' button (see Fig. 4.2) often caused visitors that were interested in further information about a media item to accidentally delete it. Although visitors usually tried to activate the information and video buttons several times, their lack of response or unintended trigger of other buttons quickly led to frustration and caused visitors, in particular children, to interact playfully but mindless with media items. In this way, opportunities to inform initially interested visitors further about the Arctic were often given away.

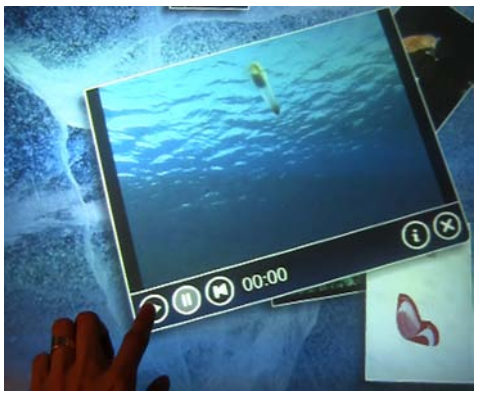


Figure 4.2: Buttons on media items.

Besides these usability issues that could be easily resolved by providing larger buttons, participants also commented negatively on the presentation of more in-depth information about media items: "*Also, when you shift to the text, it feels like work. Whereas before, the images and movement feels like play. So it* [bringing up the text, the more in-depth information] *stops your*

interaction and you are supposed to read and it is really quite dry. So whoever is writing, it is also writing in a very educational straight forward way that is not playful. So it doesn't continue the overall kind of feel." Additional information on media items could be provided in a more lightweight manner. Instead of requiring visitors to trigger information about an item through the touch of an information button, a minimum of information such as names of animals or brief descriptions could be directly presented on the photograph or video. Videos could be annotated with brief labels and comments to help visitors understand what is shown in the video snippet while the video is running.

Another usability issue that inhibited information intake is the appearance of media items on top of other items. Typically, visitors would enlarge media items that they were interested in and (in particular in case of video items) passively watch them for a while. During this time we could frequently observe new media items popping up in the middle of the item of interest and therefore disrupting visitors' exploration process.

Open-Ended Information Exploration

The loose arrangement of media items within the Collection Viewer in combination with free-form multi-touch gestures supported an open-ended information exploration and allowed for serendipitous discoveries—something that some participants really appreciated: "*It is a little bit more random, like arbitrary, what you sort of find and what you can look at. Which is kind of nice because it gives a little bit more freedom that way.* [...] *Then it is really interesting just going through: oh, there is an interesting image let's see what's there... So it is just things that capture your attention and that was ok. I kind of liked that actually.*" Other participants, however, would have appreciated more guidance through information: "*I tend to like something that is a little more guided. I am a person who doesn't really like exploring that much. I like to be led through some information so I do like the videos because I do know the order in which I am supposed to view the information whereas here it is kind of like: oh, I don't want to miss anything but, you know, I am kind of searching for the good information but I don't know if I am getting it.*" One possibility that could help to combine open-ended information exploration with some guidance would be to, for instance color code media items based on certain themes. Visitors could focus on topics they are interested in and focus on these particular media items. The notion of categorizing media items based on themes was actually suggested by one of our participants as we discuss in the following section.

Understanding of Relations between Media Items

Visitors payed attention to the annotated connection lines that indicate relations between some media items. This is evident in frequent attempts to touch or interact with these lines directly. However, the connection lines were often occluded by other media items oating by or popping up on the tabletop surface. Furthermore, in many situations they were not in the right orientation or too far away from an interested visitor to be read. Often, one media item would disappear on the table edge or was dragged away by another visitor which did not provide enough time to explore the relation between both media items further. Participants stated: "*We noticed that the lines are coming up and there would be a little tag of information but it was really hard to follow*

it. So if something would come up you could sort of see that it was connected to something else but you could not necessarily get to the image it connected to because other images would be floating over top. [...] *What was frustrating is seeing that they were supposed to be connected with the strand and not being able to track down how they are connected.*"

However, visitors were interested in learning more about contextual relationships between different media items. One participant suggested to enable arrange media items based on different themes: "*Something that could be interesting potentially is if you could choose between different themes.* [...] *For example, there are a number that actually have to do with sort of microorganisms and something like that. So it would be interesting if you could sort of select and have that as a theme. And then you could interact with all those things knowing that they were sort of related. And you are building on the knowledge.* [...] *A thematic approach but still have some randomness. But being able to select things that interest you would be nice.*"

4.2.6 Social Information Exploration

Information Exploration in Parallel

Visitors' approach to information exploration on the Collection Viewer can be categorized into individual and collaborative information exploration as well as a mixture between the two. Our observations revealed that visitors mostly browsed through media items individually without directly interacting much with other visitors. Our interviews with participants confirmed these findings. When asked how to characterize his exploration strategy with the Collection Viewer, one participant stated: "*I would say more individually browsing.*" His partner confirmed: "*I think we were doing it* [the exploration] *more separately* [...] *sharing some interesting things from time to time but more separate I think.*" Although the horizontal orientation of interactive tables has been emphasized as particularly supportive of collaboration [10], we found that this was not one of the important factors for visitors. One participants even expressed his dislike of collaborative information exploration: "*I don't want it to be a social experience.*" His partner explained: "*I mean it is like any other display. If I saw something that I wanted to show* [my partner], *I would call him over and show it to him. But it would not necessarily be like us looking at things together all the time. I mean I can imagine with children or like if I had children it would be a very different experience.*"

Collaborative Information Exploration

We did observed some collaborative information exploration among parents and their children. While most parents would stay rather passive and let their children interact, some parents would guide their children's attention to certain media items or children would show their parents or accompanying adults what they had found on the Collection Viewer. We also observed instances of parents guiding their children's interaction and showing them how to control media items by directly guiding their hands (see Fig. 4.3(a)).

However, we also observed some instances of collaborative information exploration that comes closer to a social experience of information. For instance, groups of visitors gathered around a corner of the table to watch a video together (see Fig. 4.3(b)). In these instances, media items

(a) Mother guiding child's hands in a resizing gesture.

(b) A group of visitors (around the far side of the table) watching a video together.

(c) Visitor group bringing a video item into the right position.

Figure 4.3: Instances of social information exploration on the Collection Viewer.

would typically be enlarged and moved to a central location of the table so that every group member could see them.

We noticed that this act of scaling and rearranging the media item for everyone to see was collaborative in itself where every group member would try to help to bring the item into the right position. One group member, for instance, would hold the item in place while another would touch the play button to start the video (see Fig. 4.3(c)).

Awareness between Different Visitors

As previous participant statements suggest, visitors also shifted back and forth between individual and collaborative information exploration. They would search through media items, find something of interest, and, at times, share it with other visitors. The horizontal orientation of the digital table enabled multiple visitors to explore information individually but still support some peripheral awareness of the activities of other visitors interacting at the same time. We found that this peripheral awareness in uenced visitors' information exploration in a positive way. One participant commented: "*Everyone was just looking for their own thing but the times when I would watch what someone else was doing was generally when a video would start. I would go: oh what's that.*" Along the same lines a participant from another visitor group stated: "*It is sort of interesting to see what somebody else finds and then it attracts your attention so you end up watching... like: oh, they are playing a video... that is kind of interesting.*" These instances of peripheral awareness were mostly mentioned in connection with video items but we also observed them when images were enlarge on one side of the table. The peripheral awareness supported by the horizontal display guided visitors toward information they might not have found otherwise through individual browsing. While field studies on public touch interactive wall displays have reported on the in uence of visitors' awareness on other people's interactions [2, 9, 7], we believe that this awareness has a different quality on tabletop displays where multiple visitors interact from all sides simultaneously and, therefore, are not only aware of what their direct neighbors are exploring but also of the people on the opposite edge of the table.

4.2.7 Simultaneous Visitor Interaction

The simultaneous interaction of different groups of visitors had some positive aspects such as the awareness of potentially interesting items explored by other visitors as discussed above. It sometimes also initiated some lightweight interaction between visitors that did not know each other before. For instance, strangers would try to help each other when there were interaction problems with media items. In Figure 4.4, for example, we see a girl touching the play button of a media item that the man next to her tried to get to play without success. She noticed his problem and tried to help him although they did not not know each other but came with different visitor groups. Statements from our participants confirm such casual interactions between people of different visitor groups: "*I tend to maybe try and help them interact, like show them what they need to do or I might start something, like I started a video and then I was showing the boy that was standing next to me. I am am like: oh I kind of got that video started. And he was able to see that...*" Besides helping each other, visitors who did not know each other initially also talked about information they had found in the Collection Viewer: "[...] *But he* [a boy] *was interested. And then I think I talked to, I don't know if it was his dad or another adult there, too a bit. I think they were interested looking at the green char so we talked a little about that.*"

Figure 4.4: Girl (pink sweater) helps another visitor (to her left) to get a video item to play.

However, simultaneous interactions on the Collection Viewer table also caused some interferences between visitors. At times, the Collection Viewer was very busy with up to ten visitors interacting at the same time. This was causing problems, for instance, when visitors would accidentally occlude another visitor's items with their hands or media items. Sometimes such interferences were prevented through awareness: "*There was one girl that was next to us that* [and] *as we started to toss things away she noticed that we didn't want things to cover our video and so* [...] *a couple of times I saw something* [another media item] *got close and she dragged it away.*" In many situations, however, different goals and/or exploration strategies of visitors would lead to interferences. One participant explained: "*For a lot of the period of time that we were there there was someone who had this huge picture that was obscuring everything.* [...] *We couldn't see everything in the middle.* [...] *That was a problem.*"

In particular children tended to playfully sweep media items around without paying much attention to their content or to other visitors interacting at the same time. This would interfere

with other visitors who would have liked to concentrate on certain media items but whose items often got obscured or accidentally tossed away. One participant commented: "*They* [children in general] *are not interested in looking at stuff. They just want to toss pictures around. So as somebody as, you know, actually wants to look at the pictures or read information that was a little bit annoying.*" Her partner added: "*I guess it is because you have different goals. You want to get information* [...] *and then someone else is screwing up the interaction.*" Interferences like this were the reason why all of our participants found that for the amount of information and free-form interaction the Collection Viewer is offering, a larger tabletop display would be beneficial. The following comments summarize this opinion: "*I think if it* [the table] *was bigger, it would be easier to have personal space.*", "*The size felt a little bit limiting...*" A larger table would provide more personal space for each visitor to explore items individually without interfering with the interests of other visitors. However, it has to be considered, that a larger table can also lead to less overall awareness with all its benefits described above.

4.3 Summary of Findings

The average interaction time, frequent instances of repeated interactions as well as our study participants' comments clearly show that the Collection Viewer positively added to visitors' experience of the Arctic exhibit. The presented information nicely picks up on content of the surrounding exhibits, and the interaction design enables lightweight and playful interaction with information. The application supported information exploration in a parallel as well as social way which responds to visitors' need for both individual and collaborative interaction. The horizontal orientation of the Collection Viewer table supports awareness among visitors which promotes serendipitous discoveries of information.

Some visitors expressed the wish for a better support of in-depth information exploration on the Collection Viewer. Bringing up more details on certain media items or learning about particular themes can be cumbersome. Most visitors—adults as well as children—therefore mostly engaged in playful interaction without paying much attention to the content of media items. To improve this, brief information about media items could be shown directly alongside photographs and videos instead of requiring extra interaction and button manipulations.

Furthermore, the open-ended exploration on the relatively small sized Collection Viewer table often resulted in interferences between visitors' interactions. A larger table would be beneficial to provide sufficient personal space for multiple visitors to individually explore media items while still enabling collaborative information exploration.

The following list summarizes the low-level usability issues our study revealed alongside possible solutions:

- Due to their small interactive area, the buttons of media items do not reliably react to visitors' interactions. Enlarging them might make them more responsive.
- Some buttons of media items, such as the 'information' and 'delete' button, are located in very close proximity to each other which frequently causes unexpected reactions from the system. Spacing them out more might make interactions more predictable.

- In particular enlarged media items often end up partly beyond the table's edge and therefore get deleted against visitors' intention. To prevent this, the deletion of media items along the table edges could be delayed to give visitors time to 'rescue' the item if desired.
- New media items often appear on top of enlarged items that visitors are currently focusing which interrupts the experience of information. The occlusion of existing media items by new ones could be avoided algorithmically.
- The interaction of multiple visitors at the same time often causes interferences, such as the 'stealing' of media items when one visitor (accidentally) touches a media item that another visitors currently interacts with. On an interactive table that is used by up to ten visitors at the same time such interferences are hard to prevent. However, some subtle rules could be implemented that computationally control the ownership of media items. The careful implementation of such rules is crucial to not constrain interaction with media items too much.

5 The Arctic Choices Table

The following sections describe our findings on the Arctic Choices table. We will first provide a brief overview of the Arctic Choices application and then describe aspects of visitors' activities and experiences with the application.

5.1 The Arctic Choices Application

The Arctic Choices application shows ecological, political, and economical characteristics and changes as they have emerged in the Arctic over the past years due to increased human activity in the region and global warming. The major part of the Arctic Choices application is dominated by an overview map of the Arctic (see Fig. 5.1). A magnifying lens tool can be moved across the map to help explore certain regions in more detail. Control bars on both short sides of the table allow visitors to activate and control visual layers in the map to show, e.g., the migration routes of Arctic animals, shipping routes, or the extend of the sea ice cover. They can be manipulated like dials or on/off sliders (see Fig. 5.2), similar to the ones that can be found on many commercial direct touch interfaces such as the iPhone. Some of the controls function in a binary way. For instance, the information layer showing how the magnetic pole has shifted over the years can be turned on or off. Turned on, it stays visible even if other information layers have been activated at the same time. Other controls feature more parameters that visitors can select from. The 'animal migration routes' dial, for instance, offers different Arctic animals to chose from. Similarly, the extend of sea ice cover can be shown for different time periods, including future projections. However, only one animal or the winter ice cover of one particular year can be selected at a time. The selection of another animal or year automatically deactivates the previously active layer. The content manipulated by the control bars differs on each short table edge: the controls on one table edge focus on the changes regarding the Arctic sea ice cover (see Fig. 5.2(b)) while the controls on the other table edge cover political information such as human population, shipping routes, and political boundaries (see Fig. 5.2(a)).

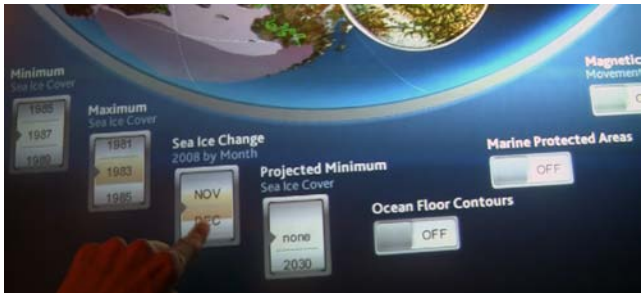
5.2 Findings on the Arctic Choices Table

The following sections describe our findings on visitors' experience and interactions with the Arctic Choices table. Similarly to the discussion of the Collection Viewer table, the findings on the Arctic Choices table are structured around the following topics:

- Overall appeal and attraction—what factors direct visitors' attention toward the Arctic Choices table?

Figure 5.1: Arctic Choices table: map, lens tool, and control bars.

(a) Animal migration routes & political boundaries.



(b) Sea ice change control bar.

Figure 5.2: Control bars for parameter selection on the Arctic Choices table.

- Duration of interaction—how long do visitors interact with the Arctic Choices table in average and how often do they come back to interact a second or third time?
- Interaction design and interaction techniques—how do visitors' learn to control and explore information on the Arctic Choices table?
- General exploration strategies—how do visitors explore information on the Arctic Choices table?
- Individual & collaborative use—how do social and collaborative interactions evolve around the Arctic Choices table?

5.2.1 The Role of the Arctic Choices Table as Part of the Arctic Exhibit

Participants' statements about information presented on the Arctic Choices table show that the content of this exhibit evoked a lot of interest. Participants found the information presented "*really important*" and appreciated the opportunity to interactively explore the provided data.

One participant stated: "*There is some really interesting information and it is nice to be actually able to compare things, for example, potential shipping routes with the migration routes of animals.*" The Arctic Choices table was vividly used by visitors of all age groups. However, in contrast to the Collection Viewer table, our observations suggest that a certain age (e.g. ≥ 8) is required to interact with the table in a meaningful way.

We noticed that participants commented a lot on things that they learned from the Arctic Choices application. For instance, the participants of one group explained: "*I didn't realize* [how] *throughout the year, like how much ice there is actually formed in the region. I didn't know that all of Hudson's bay gets filled with ice.*" Her partner added: "*It was cool to see future projections on the ice caps and how small they will get.*" Other participants were able to set information they found on the Arctic Choices table in relation to other information they already knew, e.g. from the news. One participant commented: "*I mean* [...] *actually seeing the economic zones, like what is disputed... just from what I have heard in the news and then actually seeing the areas mapped out like that...*"

All these comments show that the Arctic Choices application presents highly relevant and up-to-date information that are not only interesting to visitors but also tie in with information that visitors have previously picked up before from other media. This suggests that the Arctic Choices table might have further educated visitors about changes in the Arctic and the urgency of the topic.

5.2.2 Familiar Information as an Entry Point

Familiar Information & Personal Experiences

While visitors quickly started to explore information on the Collection Viewer table in a hands-on way, interaction with the Arctic Choices table usually started with more extended periods of watching other people interact and/or looking at the interface without touching it. One of the reasons for this could be that visitors perceived the Arctic Choices interface more carefully as much more complex (see Section 5.2.4). Many visitors therefore approached the application by just looking at its different components. Often, visitors would focus on the map first which constitutes the most visually prominent component of the Arctic Choices table and, at the same time, offers some familiar elements. Most people, especially adults, are familiar with how to read maps so they first focused on figuring out what the Arctic Choices map showed and, from there, how it was connected to the control buttons on the short edges of the table.

Furthermore, personal experiences with the Arctic drew visitors attention toward the Arctic Choices table. One participant stated: "*I think in addition it is interesting because* [her partner] *has spend a little bit of time in the Arctic.* [...] *There was some personal experience that was kind of adding us. And some of our personal curiosities about the North, too.*" We also observed some visitors trying to find certain Arctic regions within the map that they knew of.

After looking at the map for a while, visitors often tried out the control buttons on the edges of the table. Here, again, many visitors found some familiar elements because the buttons work very similar to control elements on smart phones such as the iPhone. One participant stated: "[...] *The interaction was less* [like] *touch screens in terms of large interactive touch screens and more working with my iPod touch.*" The experiences with previous small-screen touch

technology and interaction techniques therefore helped visitors to figure out how to interact with the Arctic Choices application.

The lens tool acted as an entry point as well, in particular for children who liked the direct reaction of the system when they moved the lens across the map. The Arctic Choices table, however, did not keep children engaged as much as the Collection Viewer—probably because it is less visual and information is presented in a more abstract way. Except for the lens tool, interaction with the Arctic Choices table was not experienced as playful but more analytic and, as one participant put it "*objective*".

5.2.3 Duration of Interaction and Repeated Engagement

Similar to the Collection Viewer table, the Arctic Choices table was used actively by aquarium visitors. Our high-level video analysis that included data from three study days (253 adult interactions, 272 child interactions, and approximately 6 hours of video data) revealed an average interaction time of 1.5 minutes with adults interacting for a longer period of time (1.75 minutes in average) than children (1.2 minutes in average). We observed some adult visitor groups interacting with the Arctic Choices table for as long as 20 minutes. During the analyzed 6 hours of video recordings, we counted 70 instances where the Arctic Choices table was not in use. These periods without any interaction lasted 1.08 minutes in average.

13% of the children and approximately 14% of the adults we observed interacted with the Arctic Choices table several times. Most of them came back for a second interaction but we also observed visitors who interacted for up to six times. Although a more complete analysis (including the whole data set) of the duration of interaction is required, these numbers not only show that the Arctic Choices table was vividly used by visitors but also confirms that the application seems to be more popular among adults than among children.

5.2.4 Interface & Interaction Design

Overall, all our participants perceived the Arctic Choices interface as more complex than the Collection Viewer. One could argue that the Arctic Choices table also offers more detailed and complex information and therefore requires a more elaborate interface. However, our findings on the interface design of the Arctic Choices application show that some interface elements could be simplified to make information more accessible and enable a more positive visitor experience.

Presentation of Large Amounts of Information Added Complexity

A large amount of information within the Arctic choices interface is always visible and all shown at the same level. This led participants to the impression that the Arctic Choices application appears "*overly complex*". Approaching the application for the first time, even if no information layer is active, there is a lot to process: a detailed satellite map littered with numerous labels marking different regions and cities alongside a large variety of sliders and dials controlling a variety of parameters. It requires some attention and dedication to understand what the map actually shows and how the different interface elements are connected to each other. Some visitors—and some of our participants—did not have enough patience to figure out what the

interface is all about and gave up early, lured away by other more attractive and easier accessible exhibits. One participant commented: " [...] *At the beginning it was kind of daunting because you look at it and you see all that stuff going on and you are like... like we know that if we stay there long enough we probably will understand it, whereas if I was a little bit more nervous, I might just go away and be like: oh, Jesus.*"

While the map functioned as an entry point for many visitors, its design could be simplified. This would make it easier for visitors to understand at first sight what topics the Arctic Choices application presents. For instance, the amount of labels could be minimized to those marking the most important Arctic regions and countries involved. Additional labels could interactively appear, e.g. through the use of the lens tool or simple direct touch interaction. The general appearance of the map also could be simplified by using basic outlines instead of a detailed satellite image. Along these lines, one participant commented: "[...] *There is extraneous information, too. In a sense, this looks like a satellite map* [...] *so you have color variation within the land mass. But that actually does not tell you anything that you need to know for this.* [...] *It could be just an outline. That and nothing else. And it would still make sense. So it is things like that that feel almost extraneous to me when you are trying to read all these other layers.*

Parameter Control

As discussed above visitors had no problems understanding the basic functionality of sliders and dials for selecting parameters and their according visualization layers. That being said, there were some problems that complicated the use of these controls.

We frequently observed that visitors had difficulties making the desired parameter selection because of the control's lack of response. In particular the on/off sliders were hard to control, as one participant pointed out: " *It* [the use of parameter controls] *was relatively easy to use except some buttons seem sticky. Like these sliders seem to work pretty well but these on/off switches don't work at all.*" Similarly to the 'info' and 'play' buttons of media items in the Collection Viewer table, the on/off sliders often did not readily respond to touch, probably because of their relatively small size and their proximity to the table edges that, in general, did not seem to be as responsive as the areas closer to the table center. The lack of response of these sliders is a problem because of the limited attention span of visitors. With all the different kinds of exciting exhibits in close proximity, visitors quickly gave up trying when the application did not appear to respond to their interactions. Enlarging the area of these sliders might make them more reliable for parameter selections.

We also noticed more conceptual problems with the parameter controls. As described earlier, the parameter selection using the dials sometimes disables previous selections of other dials. Figure 5.3, for instance, shows that the year '1987' has been selected in the 'Minimum Sea Ice Cover' dial. The according visualization layer appears in the map. Selecting a year with the 'Maximum Sea Ice Cover' dial, makes this previous 'Minimum Sea Ice Cover' selection disappear and brings up the 'Maximum Sea Ice Cover' selection. The 'Minimum Sea Ice Cover' dial, however, still shows the year '1987' as selected although this selection has been negated by the use of the 'Maximum Sea Ice Cover' dial. At the same time, selections made in some of the other dials allow for the according information layers to co-exist on top of each other within the map. This inconsistency in behavior made it difficult for visitors to estimate and understand

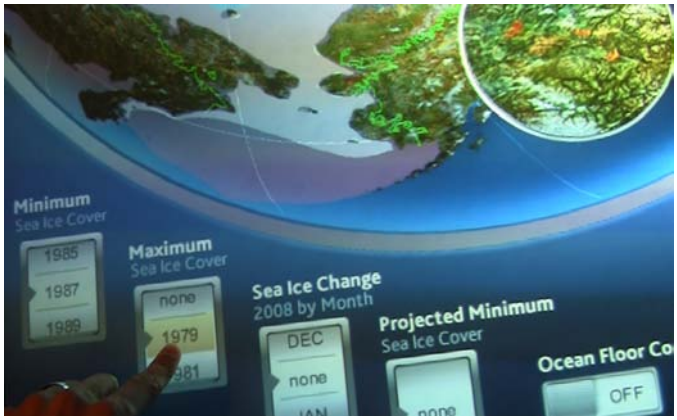


Figure 5.3: Parameter selection in different scroll wheels can negate information layers brought in through previous selections.

how their interactions with the controls effected the appearance of information layers within the map. One participant commented: "*Some of it is the understanding of what defaults off or on. Like if you choose things, sometimes it flicks other layers off. And you are not sure what it has done.*" This problem was even more persistent when several visitors interacted with controls on one table edge at the same time.

Disconnect Between Information and Control Space

Visitors quickly understood that their interaction with controls on the table edges would change visual layers within the map. However, they often had problems finding the information layer within the map that related to the particular parameter they had selected. The separation of interaction space (sliders and dials on the short edges of the table) and information space (the map in the center of the table, including the information layers) made it difficult to follow the cause-and-effect relation between parameter selection and appearance of the according visual layer. As we will discuss later, this problem was aggravated when several overlapping information layers were displayed in the map or multiple visitors interacted at the same time. Several of our participants commented on the disconnect between information and control space: "*I am touching something and I don't see immediately what I am doing so I have to look here* [at the control bar] *and then I have to look at the map if somebody else is doing something. I don't necessary know what I did that made it* [the information layer] *change.*"

Ambiguous Visual Encoding of Information Layers

The sometimes ambiguous visual encoding of information layers aggravated the problem of disconnect between information and control space. While some of the information layers are color coded in a quite intuitive way (e.g. light blue for the spread of sea ice), others are more abstract (e.g. red for animal migration routes). Especially with many layers selected and active in the map, it can be difficult to associate certain layers to the according parameters. One participant

commented: "*Here we are: 'animal migration' has some ranges. 'Bearded seal' which I guess is the purple thing* [information layer in the map]. *But then there is something yellow here, which I guess is the exclusive 'economic zones'* [she actually tries the according dial to make sure]. *So here you don't know what the 'bearded seal' range is because it is hidden by the 'economic zones'.*" Her partner added: "*It was difficult to tell exactly what it was presenting. So you know you have kind of a light red mask or something and I am not really sure exactly what that means.*" A simple legend next to the according dial might resolve this problem and make it more easier for visitors to find the layer in the map that they are currently manipulating through the controls.

Understanding the encoding of information layers is further complicated by the fact that information layers are slightly translucent. The translucency enables the presentation of multiple layers on top of each other but, at the same time, also changes the color in which information layers appear depending on the layers underneath. Even without any additional layers selected, the color of a layer appears differently depending on the colored map regions underneath. This makes it even harder for visitors to identify layers: "*It has this pale pinkish shape over top of the land mass. Like we did not even see it. So I don't know if it needs more text labels or brighter colors or maybe something a little bit more animated to notice ... not sure but it definitely needs something. So it is a bit more obvious change when you hit a button.*"

We noticed that labeled layers (e.g. political boundaries) were identified more easily. The use of labels or little icons might facilitate differentiating between information layers. For instance, instead of using a light blue for the ice layer one could use a texture consisting of ice crystal shapes. Accordingly, animal silhouettes could represent animal migration routes. Furthermore, layers could be labeled on their edges to help to identify them. However, overlapping labels of different layers might be hard to read and introduce visual clutter.

Some confusion occurred even with labeled information layers. The 'magnetic north' layer, for instance, shows the different positions of the north pole across the years. Each position is marked with a colored circle and labeled with the according year. Nothing within the visual layer, however, indicates what these labeled positions actually represent. We found that visitors frequently misinterpreted them with changes of the sea ice across the years. This example illustrates again the problem of disconnect between control and information space. It also points out the importance of labeling things in an unambiguous way to avoid misinterpretations. A brief look at the map and its visual layers should tell a clear story—without the need to look from the map to selected parameters in the control bars.

5.2.5 Character of Information Exploration

As described earlier, visitors started their information exploration on the Arctic Choices table often by looking at the map for a while, trying to figure out what it represented. This was followed by an exploration of the dials and sliders in the control bars. In this phase, visitors' focus usually went back and forth between the control bars and the map, trying to understand the relation between the presented information layers and parameter selections.

The Role of the Map

Participants liked the presentation of a map on a horizontal surface, maybe because traditional tables are naturally used to explore paper maps. One participant commented: "*I think the map interface* [...] *works really well in terms of your relationship to the table.* [...] *A map interface works well because you have a birds-eye-view.*" While the map takes up most of the Arctic Choices interface, its role is mostly passive. The important interactions happen on the control bars while the map mostly displays information rather than enabling active information exploration. Visitors, standing on the long edges of the table, therefore mostly watched the changes in the map, unable to directly in uence or further explore the presented information layers. Most participants asked for more interactive capabilities of the map. For instance, they suggested the support of interactive map rotation to be able to see information from different perspectives without having to walk around the table. As we will discuss in the following section, the addition of more functionality to the interactive lens tool could make the map a more interactive space that invites for direct information exploration.

The Role of the Lens Tool

The lens tool with its interesting visual effects triggered a lot of attention, in particular among children. Adult visitors often made use of it as well but, similar to children, more for the interactive fun of it than for information exploration purposes. In fact, from our participants we learned that the lens tool in its current design is "*fun and cool*" but did not really add any useful information: "*The zoom thing is pretty great but, you know, there is all these names here but what do they really tell you?*" Another participant commented: "*For instance, when we wanted to look at Cambridge Bay, there is stuff you cannot really see. You can put it* [the lens tool] *over top but it is almost too zoomed in so then you really loose any context at all.*"

It would be interesting to provide visitors with different *magic* lens tools [1] that, instead of just magnifying information that is already visible, *add* information about the region effected by the lens. A magic lens, for instance, could provide information on animals or human populations living in the region covered by the lens. It could also bring up additional information on the selected geographic region such as elevation or temperature or reveal a photographic layer (just within reach of the lens) showing the ora and fauna of the selected region. Such additional lens tools would not need to be visible in the map interface all the time but could be brought up by visitors by just touching the map. A benefit of providing information interactively through lens tools is that visual clutter within the map can be avoided by showing details on demand just for certain map regions. Furthermore, it would make the map a more active part of the Arctic Choices interface and encourage a more direct form of information exploration.

Open-ended Information Exploration

In contrast to the Collection Viewer table, the look-and-feel of the Arctic Choices table interface is more structured: while it can be difficult to maintain an overview of what parameters are currently selected and active within the map, the control bars make it clear where most of the interaction takes place and what range of information is available. Some participants appreciated this more structured look-and-feel that, at the same time, still supports open-ended information

exploration where visitors can focus on the particular information they are interested in. However, many participants mentioned how they would like to see the different parameters split up in a number of different small-screen interfaces to limit the amount of information shown on a single display.

Exploring Parameters One by One

To gain an overview of how the controls relate to the information layers displayed, we noticed that visitors would often try to disable all parameters first, and then, one by one, bring in different information layers in a very controlled way. While this strategy seemed to be very effective for visitors' understanding of the presented information, this was only possible in time periods where only few people interacted with the table at the same time.

5.2.6 Social Information Exploration

In contrast to the Collection Viewer, where visitors explored information mostly in parallel and only occasionally shared certain aspects of information or started to collaboratively interact with information items, we found that collaborative information exploration was more common with the Arctic Choices table. Maybe because of the complexity of the interface, visitors discussed information they found and the general functionality of the interface more actively with their family, friends, partners, and even other visitors they did not know before. Participants mentioned that they actively discussed the results they received from certain parameter selections within their group. They also collaboratively decided on what to select next.

It was interesting to see that visitor groups would often have one person in charge of the parameter selection while the rest of the group would more passively watch and discuss the effects within the map or direct the parameter selection from afar. We believe that this behavior that we did not observe on the Collection Viewer is a result of the Arctic Choices interface. The Arctic Choices table does not support parallel information exploration very well. The two control panels on the short side of the table allow two groups of visitors to interact at the same time. However, simultaneous interaction of several visitors on one side of the table can be cumbersome, because some of the dials neglect each others selections as discussed before. Furthermore, all participants commented on the difficulty of maintaining an overview of the selected parameters and the corresponding information layers. As more visitors interact at the same time, keeping track of changes in the map that relate to certain parameter selections becomes even more difficult. Even within one group, visitors therefore seemed to find it easier to limit the interaction of multiple people as much as possible.

One positive aspect of this more collaborative interaction is that visitors focused on certain information aspects and actively discussed them within a group. Furthermore, discussions often focused more on the information presented on the Arctic Choices table whereas interaction with the Collection Viewer often did not go beyond playfully tossing media items around.

5.2.7 Simultaneous Visitor Interaction

Visitors discussed a lot within their own group but also with strangers about the information presented on the Arctic Choices table and how the visual representations were to be read. It seems that form factor of the table, similar to the Collection Viewer, supported some awareness between visitors interacting at the same time and, therefore, visitors might have felt more open to make comments or ask questions, even to other visitors they did not previously know. Along these lines, one of our participants commented: "*It was funny because I almost felt like I wanted to talk to him* [a stranger interacting with the Arctic Choices table at the same time] *to sort of explain how things work.* [...] *Like if somebody was really trying to figure something out then I would probably be like: oh yeah, we figured that out how to do that...*"

Despite of this positive aspect, we found that the simultaneous interaction of visitors had some negative effects as touched on before. All participants mentioned that the interaction of multiple people with the Arctic Choices interface in its current design makes it difficult to understand the meaning of the different information layers and what brought them up. One participant stated: "*I would be reluctant to spend a lot of time on it* [the Arctic Choices table] *because there is so many people around it. So like, you know, it kind of interferes with what you are doing on your own. If I was on my own* [...] *I'd spend 10 to 15 minutes.*" A participant from another group gave an example of such interfering interactions: "*So I was using the sea ice layers and I could not figure out what was the sea ice boundary and suddenly the political boundaries were turned on.*"

Visitors were quite aware of their interactions possibly interrupting other visitors' exploration. This awareness might even have hampered visitors' own explorations as this participant's statement suggests: "*One thing that I was pretty tentative about was someone else was doing some stuff and I didn't want to interrupt that. You know, you put an overlay over top and it gets confusing. Something just pops up.*"

It is because of such interferences, along with the overall density of information on the Arctic Choices table, that a lot of participants suggested to divide the current amount of information into several small display interfaces. Participants thought that this solution would still enable a social experience of information within a group but make it easier to understand the meaning of visual layers and avoid interferences caused by other visitors' interactions. One participant suggested: "*There is so much information on it that it gets kind of too confusing. And you have to be really dedicated to understand how it works. I mean, it just seems easier if it would be different screens that would be easier to understand if this is for dissemination of information.*" A participant from another group suggested the use of vertical displays in combination with a larger display installed higher up to make it possible to observe visitors' interactions from afar. The aquarium already makes use of this kind of setup in other exhibits.

5.3 Summary of Findings

Visitors were highly interested in the information that the Arctic Choices table has to offer. This interest manifested itself in a vivid use of the tabletop application. From study participants' comments we found that visitors learned new insights about the Arctic from their exploration of the Arctic Choices application and were able to set the information they found in relation to

their previous knowledge of the Arctic. Visitors also actively discussed information they found on the Arctic Choices table with other visitors and often engaged in collaborative information explorations.

However, we found some problems with the interface design of the Arctic Choices table that complicated visitors' exploration and understanding of the presented information. First of all, the Arctic Choices interface is divided into a control space (the control bars on both short table edges) and an information space (the map where visual information layers appear). This divide makes it difficult for visitors to understand the relation between their interactions in the control space (parameter selection) and the corresponding visual information layers in the information space.

Furthermore, the form factor of the Arctic Choices table invites for the interaction of multiple visitors at the same time. Yet, the Arctic Choices interface lacks of support for multi-person interaction and parallel information exploration. The interface mainly provides two interaction spaces: the control bars on both short table edges. Technically, multiple visitors can interact in these spaces at the same time. In practice, however, the interaction of several people at the same time causes the map—the information space—to become overcrowded with information which makes it hard to keep track of whose interactions caused certain changes within the map. The amount of information combined with the sometimes ambiguous visual representation of information layers, makes it difficult for visitors to understand the meaning and relation of the presented information.

We also noticed a number of low-level usability issues listed below.

- The presentation of large amounts of information within the map adds complexity to the overall look-and-feel of the Arctic Choices interface. Some of the visual representations could be simplified, for instance, by reducing the number of labels and geographic details within the map.

- Visitors found it hard to associate the visual information layers within the map with the corresponding parameter selection in the control bars. The visual representation of information layers within the map is rather abstract and sometimes ambiguous. The careful use of legends within the control bars, showing the colors and/or visual representation of information layers within the map could help to make the relation between selected parameters and information layers more clear. Similarly, labels and icons within the information layers could clarify their meaning.

- The visual design of dials should make clear how the selection of parameters will effect the visibility of previously selected parameters of other dials.

Despite of these problems, many visitors managed to understand some of the visual encoding of information layers. However, this basic understanding required a considerable amount of patience and attention. We observed some visitors that were really interested in the presented information and spend as long as 20 minutes with the Arctic Choices table, carefully exploring and discussing the meaning of the parameters and visual layers. However, we also observed many visitors who gave up early, overwhelmed by the amount of information and the complexity of the interface.

We believe that the main problem of the interface is that different parameters can be controlled by multiple visitors independent from each other but are represented in one central part of the interface (the map) where they accumulate to a complex mass of information that is difficult to keep an overview of. We therefore suggest to break down the interface and allow visitors to control parameters in a more local and direct way. This could be realized through the use of multiple screens. Another approach could be to use a tabletop display and keep a simplified version of the Arctic map representation but arrange for a more direct control of parameters, for instance, through the use of magic lens tools as discussed in Section 5.2.4.

6 Conclusion & Future Directions

Both the Collection Viewer and the Arctic Choices table enhance the Canada's Arctic exhibit in different ways. The Collection Viewer supports an open-ended and lightweight way of exploring information at a high level. The Arctic Choices table offers a large variety of more complex information to choose from and to explore more in-depth. The Collection Viewer attracted especially younger visitors' curiosity through playful interaction. Children interacted slightly longer than adults with the Collection Viewer. In contrast, the more analytical interface and abstract information of the Arctic Choices table attracted the attention of more adult visitors, visible in a longer average interaction of adults.

We found that visitor interaction with the Collection Viewer can be mostly characterized by parallel interaction with occasional collaborative instances of sharing and discussing information. In contrast, visitors collaborated more closely when exploring information on the Arctic Choices table. Our findings suggest that this the collaborative information exploration on the Arctic Choices table is enforced by its interface design that does not support parallel interaction of visitors well and, by the higher complexity of information and its representation that invites for more vivid discussions among visitors.

While we received positive comments from study participants about the topics and information details that the Arctic Choices table covers, they described the Collection Viewer as "*more visually interesting*" and "*more engaging*". However, we strongly believe that the simplification of the Arctic Choices interface can improve visitors' experience.

In general, our study has shown that the use of large interactive display technology opens up new ways of information exploration within public exhibition spaces. In particular the combination individual and collaborative as well as open-ended and self guided information exploration, that large digital tables can support, can be seen as a chance to disseminate information in an engaging way.

Future Directions of Study

The findings described in this report provide a broad overview of visitor interactions and experiences with the Collection Viewer and the Arctic Choices table. We plan to further analyze the very rich data set that we were able to gather during our study at the Vancouver Aquarium. In particular, we would like to analyze in more detail how collaboration and social information exploration evolves around the two different tabletop installations. Furthermore, we have already started an in-depth analysis of the range of multi-touch gestures that visitors apply on the Collection Viewer.

7 Appendix: Visual Interaction Analysis

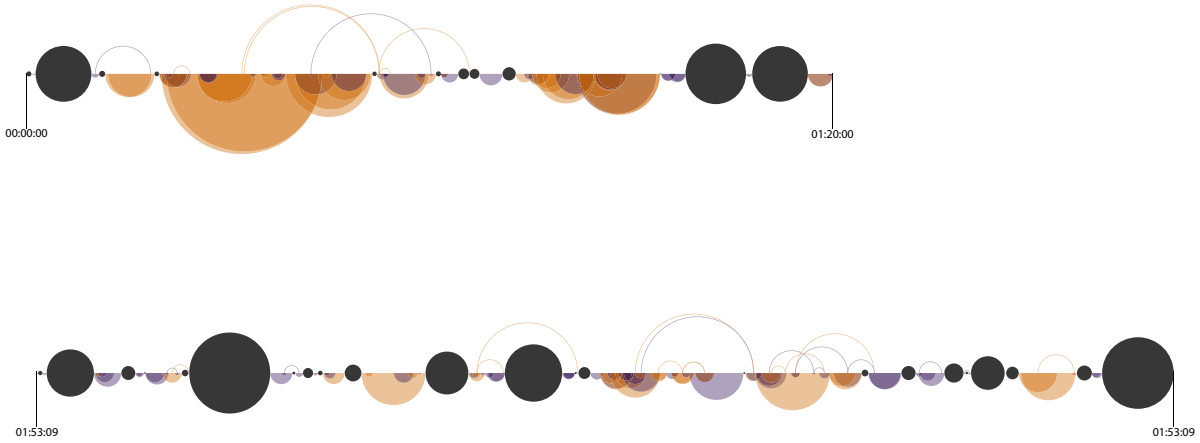


Figure 7.1: Collection Viewer table—12-12-2009.

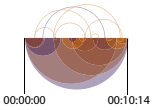


Figure 7.2: Collection Viewer table—12-31-2009.

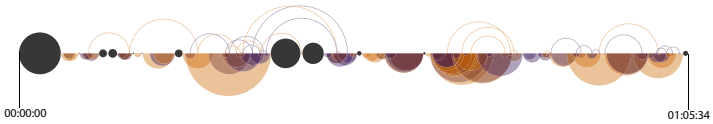


Figure 7.3: Collection Viewer table—01-01-2010.

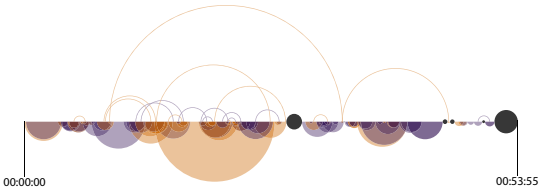


Figure 7.4: Collection Viewer table—01-02-2010.

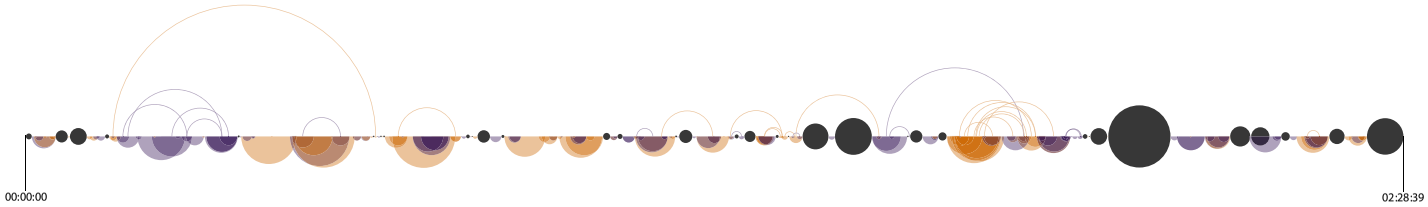


Figure 7.5: Arctic Choices table—12-31-2009.

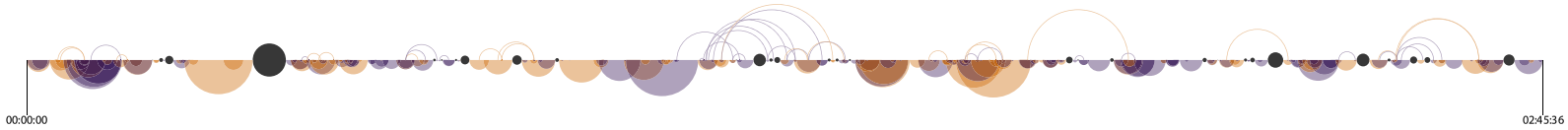


Figure 7.6: Arctic Choices table—01-01-2010.

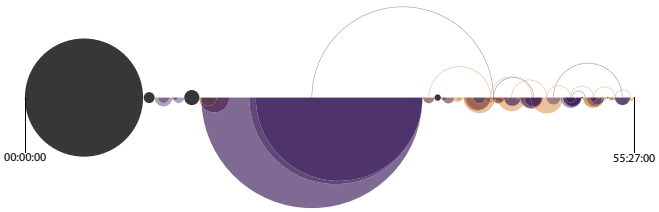


Figure 7.7: Arctic Choices table—01-02-2010.

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